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## (54) Electroacoustical transducer.

(57) An electroacoustical transducer cone assembly comprises a continuous fabric layer (20). This layer extends into both a cone body region (12) and a surround region (14) of the assembly. The fabric layer may be woven and have a first fibre and a second fibre acting as an adhesive.

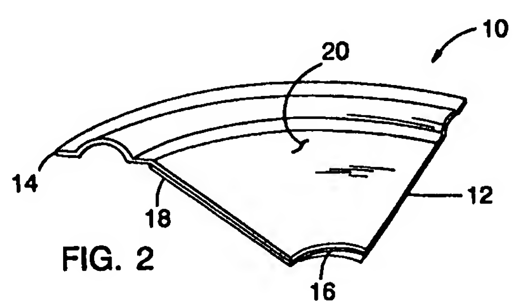


FIG. 2

EP 0 508 596 A1



3/16/2006, EAST Version: 2.0.3.0

The invention relates to electroacoustical transducing and more particularly to cone assemblies therefor.

Large displacement, acoustic transducer cones (e.g., for loudspeakers) typically comprise a three-piece assembly of a paper cone body, a urethane foam or cloth surround, and a paper, thermoplastic or metal dust cap adhesively bonded together. A thermoplastic, injection-molded cone body reinforced with a discontinuous fiber system and thermoplastic, vacuum- or pressure-formed cone bodies are also known. Small displacement tweeters may comprise one-piece cone assemblies.

In one aspect, the invention features an electroacoustical transducer cone assembly, such as for a loudspeaker that includes a continuous fabric layer extending into both the cone body and more compliant surround regions of the assembly. Preferred embodiments include the following features. The fabric layer resides in the cone body region to a greater extent than in the surround region, and the fabric layer also includes the dust cap region of the assembly. The fabric layer includes a thermoplastic polymer fiber (most preferably a liquid crystal polymer fiber) and a stiffening adhesive introduced into the fabric as a second fiber having a lower melt temperature than the first fiber. Preferably, the second fiber is also a liquid crystal polymer fiber. However, other fibers having the appropriate melt temperature characteristics of a thermoplastic fiber, such as polyester, can also be used. Preferably, the cone body region is acoustically opaque.

In another aspect, the invention features a cone assembly having a three-part structure, the cone body region or the surround region of which includes a thermoplastic polymer fiber, preferably a liquid crystal polymer fiber.

Preferably the fabric for the cone surround assembly is woven. However, any method for forming the fabric, such as knitting or forming in a felt process, can be used.

A large displacement, fabric transducer cone formed by selective consolidation of textile yarns has high stiffness in the cone body and high compliance in the surround that is of compliance higher than that of the cone body and yet consists of a single piece of material with the full-range radiation characteristics of a conventional cone body, surround, and dust cap combination. Not having the adhesive-caused transitional regions resulting from multi-piece assembly of a separate cone body, surround, and dust cap, the one-piece cone has more consistent mechanical behavior and improved acoustic performance. A one-piece cone also benefits from reduced mass in the absence of adhesives.

A transducer cone made from a thermoplastic polymer fiber, especially a liquid crystal polymer (LCP) fiber, has substantially better resistance to moisture and to elevated temperature than traditional paper and vacuum-formed cones. The thermoplastic polymer fiber system also possesses good fatigue resistance to survive the rigors of high output sound reproduction over extended periods of time.

Other features and advantages of the invention will be apparent from the following description and from the claims when read in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of an LCP transducer cone;

FIG. 2 is a sectional view of an LCP cone, taken at lines 2-2 in FIG. 1;

FIG. 3 is a schematic view of a section of fabric for an LCP cone; and

FIG. 4 is a view of a die set-up for fabricating an LCP cone.

A large displacement, fabric transducer cone assembly (a full-range acoustic transducer with high surround compliance and excellent fatigue resistance, producing frequencies from below 100Hz to over 10kHz) is formed by selective consolidation or compression of a fabric composed of two or more yarn types. In the cone body and dust cap regions the yarns are selected so that at least one type (called the "fiber yarn") provides stiffness (i.e., has a high elastic modulus) and at least one other type (called the "binder yarn") functions to bond the fiber yarns together. The surround and region of the fabric preferably comprise only fiber yarn. Upon treatment in a heated-platen press these regions assume their finished shape and retain their characteristic resiliency. The yarns are processed into flat goods by either weaving, knitting or felting, and the bonding of the yarns in the cone is preferably accomplished by melting the binder yarns and permitting them to impregnate the fiber yarns under pressure. The fiber yarns have a melt temperature that is sufficiently higher than that of the binder yarns so that the fiber yarns retain their stiffness during the required temperature cycling.

By controlling temperature and pressure during the forming process, the selective consolidation of the fabric between matched dies may be regulated to provide the desired properties in the cone body, the surround and the dust cap. The degree of consolidation (i.e., compression of the fibers or of the fabric layers) is controlled by the clearances of the machine dies and the specific pressure forcing the die halves together. In areas of small clearance and high pressure, a composite material is produced as the binder yarn melts and flows out to capture the fiber yarn. In areas of greater clearance and lower pressure, the fabric is not consolidated,



3/16/2006, EAST Version: 2.0.3.0

remaining loose and more compliant. This parameter selection allows high stiffness in the heavily consolidated region of the cone body and high compliance in the lightly consolidated surround. For additional stiffness in the cone body and enhanced acoustical characteristics, a second textile layer may be consolidated with the first, specifically in the cone-body-designated region of the textile.

In addition, a transducer cone of exceptional resistance to both stress relaxation and environmental exposure may be produced by taking advantage of the special properties of a thermoplastic polymer yarn made from a liquid crystal polymer (LCP) fiber. A liquid crystal polymer forms a phase which has both crystalline and liquid properties, that is, parts of the polymer molecules have a degree of order between the very regular three-dimensional orientational and positional order of a crystalline phase and the high disorder of a liquid. Liquid crystalline materials are characterized by long-range orientational order and by a lack of positional order in at least one dimension.

The transducer cone described herein is preferably made from Vectran, a thermoplastic polymer yarn composed of a liquid crystal polymer (LCP) fiber (Hoechst Celanese Corporation, Fibers and Film Group, Charlotte, NC). The fabric of the cone is preferably formed from two different Vectran yarns having two different melt temperatures: Vectran HS ($T_m$ = 625-630 °F) and Vectran M ($T_m$ = 525-530 °F).

Referring to FIG. 1, a one-piece transducer cone 10 has a stiff, two-ply cone body region 12, a compliant, single-ply surround region 14, and a two-ply dust cap region 16. Referring also to FIGS. 2 and 3, the bottom ply 18 of cone body region 12 is a five-harness satin weave textile composed of one strand each of 200 denier Vectran HS and 200 denier Vectran M plied together in both the warp and fill direction at approximately 45 yarns per inch. A five-harness satin weave is defined as a woven fabric wherein a given strand passes over four cross strands and under one cross strand. Thus there are five cross strands in the repeating unit. This pattern is repeated in both directions.

Top ply 20 (forming surround region 14, dust cap region 16, and the upper portion of cone body region 12) is a five-harness satin weave composed of one strand of 200 denier Vectran HS only. It is woven in both warp and fill directions at approximately 60 yarns per inch. This ply functions as the complete surround region and is preferably sealable, while still maintaining its spring-like character at the edges. As part of the cone body region, this ply enhances the radiation characteristics of the cone body region by increasing stiffness from the increased section thickness. A variety of weave types have been successfully employed in both plies, including eight-harness satin, five-harness satin, twill and plain weaves. The five-harness satin weave is preferred because of its forming characteristics.

A heated-platen press with a matched set of dies specifically in the shape of the cone body, surround and dust cap is used to form a one-piece cone assembly. The dies are preferably carefully machined so that the clearance between the die halves when the dies are fully closed varies across the die cross section. In the cone body region the clearances are preferably chosen so that the fabric compresses approximately 30%, e.g., on a two-ply fabric where each ply is approximately 0.008" thick, the die clearance is 0.011". In the surround area the clearance is set to be the same as the thickness of the fabric to be shaped so that no compression occurs. This compression variation results in a 100 fold difference in section modulus (i.e., cone to surround stiffness) between the two areas.

Referring to FIG. 4, a 5.5" by 5.5" square of top ply fabric 31, formed as described above, is first preconsolidated, for reduced surround porosity, in flat dies (not shown) in a heated-platen press where temperature and pressure may be varied. Beneficial effects have been realized at pressures from 100-7000 psi and temperatures between room temperature and 400 °F. The preferred range is 2000-5000 psi at 300 °F for 0.5-5 minutes.

The top ply fabric is then aligned with a preformed cone without surround as the bottom ply fabric 32 and placed in a matched set of dies 33 and 34 (preheated to 560 °F by upper heated platen 35 and lower heated platen 36, respectively) having a shape corresponding to a typical 4.5" loudspeaker driver cone. The temperature is selected to melt the Vectran M while leaving the Vectran HS intact. The dies are closed by moving shaft 37 toward base 38, reheated to 560 °F, and pressed together at a pressure of approximately 25 psi to form the cone assembly. After three minutes the heat to the platens is discontinued, the dies are cooled, and the cone is removed from the press. Cooling may be as rapid as the process configuration will allow since the composite cone assembly is not sensitive to cooling rate. In the fully formed cone assembly the Vectran M (binding fiber) of the bottom ply impregnates not only the Vectran HS fibers of the bottom ply, but also those of the top ply, thus fusing the two plies together. The Vectran M material does not penetrate into the surround region of the fiber.

In another example, a woven fabric composed of Vectran HS and Vectran M were plied together to obtain a single yarn with approximately 30% Vectran M. This yarn was then woven into an eight-



3/16/2006, EAST Version: 2.0.3.0

harness satin fabric having an area-density of approximately 125 g/m$^2$ to be used in the lower ply.

In a third example, the same Vectran HS yarn was cut in 1-3" inch long fibers and blended with Kodel 41D (a thermoplastic polyester yarn produced by Eastman Kodak) so that the mixture was composed of approximately 20% Kodel 41D. This mixture was then processed into a lightweight needle-felt (i.e., a non-woven flat fabric). This felt fabric was then cut into a 5.5" by 5.5" sample and formed as described before as a single ply into a cone and surround.

An LCP cone and surround assembly built into a loudspeaker driver permits large cone motion with surround compliance comparable to conventional multi-piece cone assemblies. Measurements of free-air resonance on the LCP cone and typical Bose two-piece paper cone-surround assemblies have shown essentially equivalent free-air resonance, a measure of the transducer compliance. The invention is especially useful for transducers capable of large cone displacement, typically where the ratio of maximum cone displacement to cone diameter is at least .125/4.5.

Other embodiments are within the following claims. For example, to achieve the desired acoustic characteristics in the cone body region, additional layers of formed fabric samples may be laminated together during or after the forming process. The bottom plies are preferably composed of 25-50 volume percent melting fiber.

The cone body region may also be formed from a single ply. As the entire surround, cone body, and dust cap regions are then made from the same single-ply layer, containing both fiber yarns and binder yarns, the surround region of the dies is preferably kept below the melting temperature of the binder yarns while the cone and dust cap regions are heated above the binder yarn melt temperature, as described above. In this way a complete, large displacement cone, having desired stiffness in the cone body and resiliency of the surround and dust cap regions, is formed from a one-piece, single ply fabric.

A cone assembly having a three-part structure and taking advantage of the properties of thermoplastic polymer fibers in either or both of the cone body and the surround region of the assembly is also within the claims.

Although thermoplastic polymer fibers are disclosed in these examples, other materials could be used to produce consolidated, one-piece fabric cones. By selection of fiber yarns it is possible to obtain any desired compliance characteristics by changing the die forming process.

## Claims

1. An electroacoustical transducer cone assembly comprising a continuous fabric layer (20), the layer extending into both a cone body region (12) and a surround region (14) of the assembly around the cone body region.

2. An assembly according to claim 1, wherein the fabric layer resides in the cone body region to a greater extent than in the surround region.

3. An assembly according to claim 1 or claim 2, wherein the fabric layer further comprises a dust cap region (16) within the cone body region.

4. An electroacoustical transducer cone assembly, a region of the assembly comprising a fabric comprising a thermoplastic polymer fiber.

5. An assembly according to claim 4 wherein said region comprises a cone body region (12).

6. An assembly according to claim 4 or claim 5, wherein the region comprises a surround region (14).

7. An assembly according to any of claims 1 to 3, wherein the fabric comprises a thermoplastic polymer fiber.

8. An assembly according to any of claims 4 to 7, wherein the thermoplastic polymer fiber comprises a liquid crystal polymer fiber.

9. An assembly according to any of claims 4 to 8, wherein the fabric further comprises a stiffening adhesive.

10. An assembly according to any of claims 1 to 3, wherein the fabric comprises a first fiber and a stiffening adhesive.

11. An assembly according to claim 9 or claim 10, wherein the adhesive is a second fiber having a lower melt temperature than that of the first fiber.

12. An assembly according to claim 11, wherein the second fiber comprises a polyester fiber.

13. An assembly according to claim 11, wherein the second fiber comprises a liquid crystal polymer fiber.

14. An assembly according to any of claims 1 to 13, wherein the fabric layer is woven.



3/16/2006, EAST Version: 2.0.3.0

**15.** An assembly according to any of claims 1 to 13, wherein the fabric layer is knitted or formed by a felt process.

**16.** An assembly according to claim 1 or claim 5 or any claim when dependent thereon, wherein the cone body region is acoustically opaque.

**17.** An assembly according to claim 1 or any claim when dependent thereon, wherein the compliance of the surround region (14) is greater than that of the cone body region (12).



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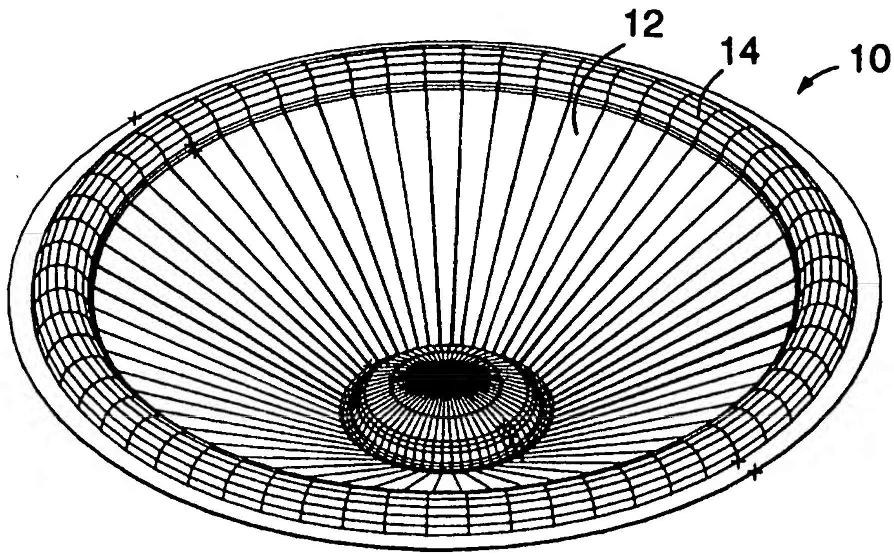


FIG. 1

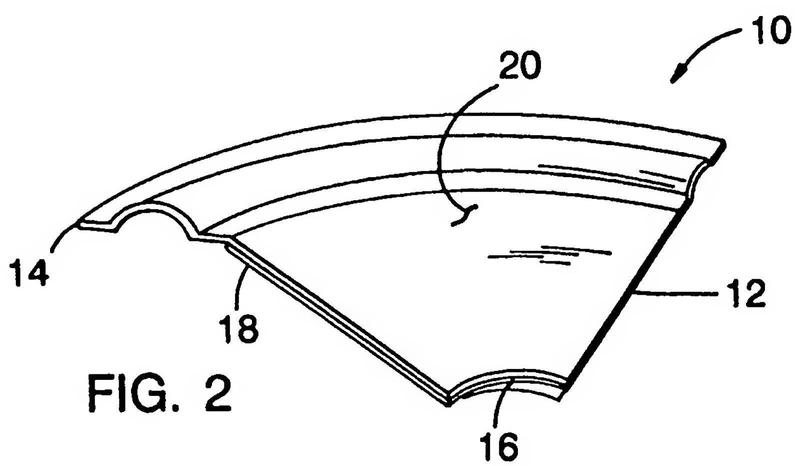


FIG. 2



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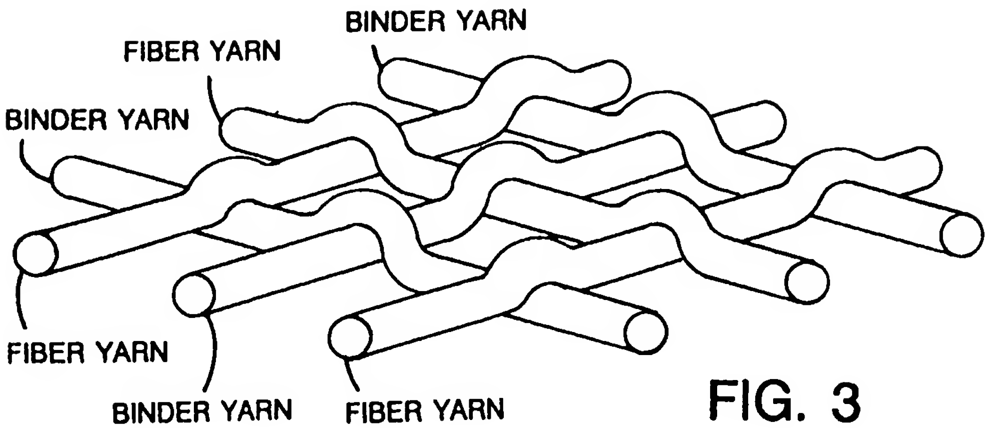


FIG. 3

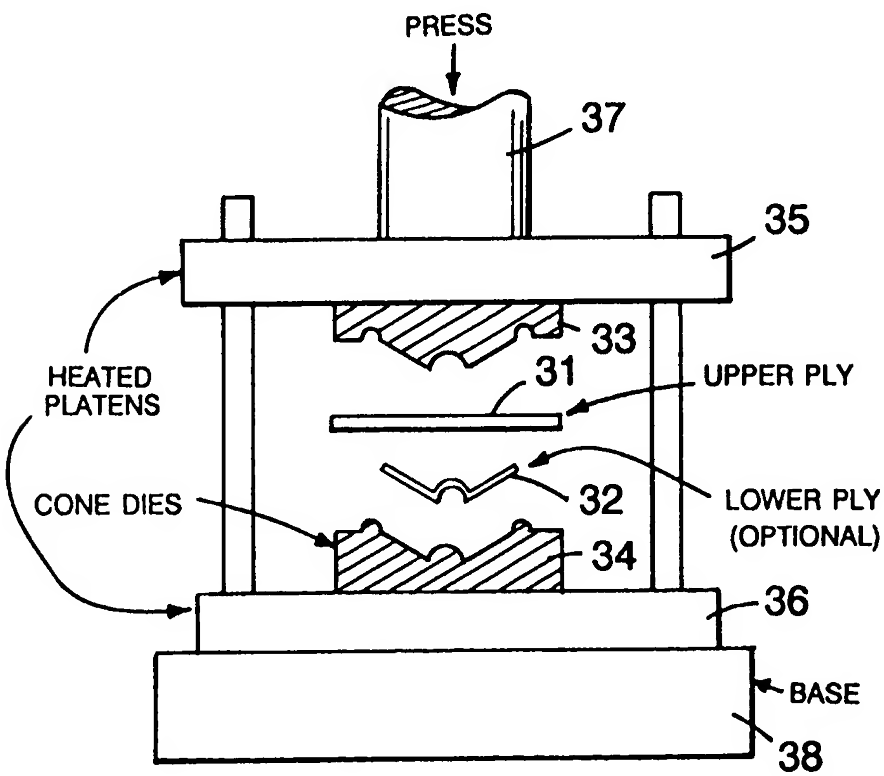


FIG. 4



3/16/2006, EAST Version: 2.0.3.0

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# EUROPEAN SEARCH REPORT

Application Number

EP 92301981.4

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| X | GB - A - 2 094 701 (MATSUSHITA) * Abstract; column 1, line 1 - column 1, line 109; fig. 4; claims 1,8 * -- | 1 | H 04 R 7/12 |
| A | DD - A - 263 906 (VEB FUNKWERK KÖLLEDA) * Totality * -- | 1 | |
| A | DE - A - 3 622 558 (ANT NACHRICHTENTECHNIK) * Totality * ---- | 1 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H 04 R

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| VIENNA | 28-07-1992 | GRÖSSING |

CATEGORY OF CITED DOCUMENTS

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